EXPRESS MAIL LABEL NO:
EL 699 357 137 US

STRICTLY NONBLOCKING MULTICAST MULTI-STAGE NETWORKS

Venkat Konda

CROSS REFERENCE TO CD-ROM APPENDIX

Appendix A includes software written in the C programming language for a prototype of a scheduling method to set up connections through a three-stage network. The C code is compilable by Visual C++ compiler, version 6.0 available from Microsoft Corporation, to form an executable file for use in an IBM compatible personal computer. Appendix A also includes documentation in a readme file for the C code and also instructions on how to compile and execute the C code.

```
                                 cddir
Volume in drive D is 010925_1627
Volume Serial Number is 08C3-4D4A

Directory of D:\

09/25/01                 04:27p     <DIR>
09/25/01       04:27p    <DIR>
09/25/01       04:27p    <DIR>          M-1222~1
               3 File(s)               0 bytes

Directory of D:\M-1222~1

09/25/01                 04:27p   <DIR>
09/25/01                 04:27p   <DIR>
09/21/01                 11:42a    57,057 OUT1.RTF
09/21/01                 11:36a     1,600 README.TXT
09/21/01                 11:42a    30,378 SNB.C
5 File(s)                          89,035 bytes

Total Files Listed:
8 File(s)                          89,035 bytes
                                        0 bytes free
```

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to and incorporates by reference in its entirety the related U.S. Patent Application Attorney Docket No. M-12158 entitled "REARRANGEABLY NON-BLOCKING MULTICAST MULTI-STAGE NETWORKS" by Venkat Konda assigned to the same assignee as the current application, and filed concurrently.

BACKGROUND OF INVENTION

As is well known in the art, a Clos switching network is a network of switches configured as a multi-stage network so that fewer switching points are necessary to implement connections between its inlet links (also called "inputs") and outlet links (also called "outputs") than would be required by a single stage (e.g. crossbar) switch having the same number of inputs and outputs. Clos networks are very popularly used in digital crossconnects, switch fabrics and parallel computer systems. However Clos networks may block some of the connection requests.

There are generally three types of nonblocking networks: strictly nonblocking; wide sense nonblocking; and rearrangeably nonblocking (See V.E. Benes, "Mathematical Theory of Connecting Networks and Telephone Traffic" Academic Press, 1965 that is incorporated by reference, as background). In a rearrangeably nonblocking network, a connection path is guaranteed as a result of the network's ability to rearrange prior connections as new incoming calls are received. In strictly nonblocking network, for any connection request from an inlet link to some set of outlet links, it is always possible to provide a connection path through the network to satisfy the request without disturbing other existing connections, and if more than one such path is available, any path can be selected without being concerned about realization of future potential connection requests. In wide-sense nonblocking networks, it is also always possible to provide a connection path through the network to satisfy the request without disturbing other existing connections, but in this case the path used to satisfy the connection request must

be carefully selected so as to maintain the nonblocking connecting capability for future potential connection requests.

U.S. Patent 5,451,936 entitled "Non-blocking Broadcast Network" granted to Yang et al. is incorporated by reference herein as background of the invention. This patent describes a number of well known nonblocking multi-stage switching network designs in the background section at column 1, line 22 to column 3, 59.

An article by Y. Yang, and G.M., Masson entitled, "Non-blocking Broadcast Switching Networks" IEEE Transactions on Computers, Vol. 40, No. 9, September 1991 that is incorporated by reference as background indicates that if the number of switches in the middle stage, m, of a three-stage network satisfies the relation $m \geq \min\left((n-1)(x+r^{1/x})\right)$ where $1 \leq x \leq \min(n-1, r)$, the resulting network is nonblocking for multicast assignments. In the relation, r is the number of switches in the input stage, and n is the number of inlet links in each input switch. Kim and Du (See D.S. Kim, and D. Du, "Performance of Split Routing Algorithm for three-stage multicast networks", IEEE/ACM Transactions on Networking, Vol. 8, No. 4, August 2000 incorporated herein by reference) studied the blocking probability for multicast connections for different scheduling algorithms.

SUMMARY OF INVENTION

A three-stage network is operated in strictly nonblocking manner in accordance with the invention includes an input stage having r_1 switches and n_1 inlet links for each of r_1 switches, an output stage having r_2 switches and n_2 outlet links for each of r_2 switches. The network also has a middle stage of m switches, and each middle switch has at least one link connected to each input switch for a total of at least r_1 first internal links and at least one link connected to each output switch for a total of at least r_2 second internal links, where $m \geq 2 * n_1 + n_2 - 1$. In one embodiment, each multicast connection is set up through such a three-stage network by use of at most two switches in the middle stage. When the number of inlet links in each input switch n_1 is equal to the number of outlet links in each output switch n_2, and $n_1 = n_2 = n$, a three-stage network is